Boeing Technology

Improvements in Surface Preparation Methods for Adhesive Bonding

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Project Description - PP-0204

The purpose of this project is to:

•Demonstrate and validate the laboratory-verified, sol-gel processes developed under SERDP PP-1113 by addressing implementation issues for aluminum, titanium, and steel substrates utilized by tri-service aircraft platforms at the repair (depot and field) and OEM levels.

Dual Use Technology Development

AFRL/MLSA NAVAIR TACOM-ARDEC BOEING

DEMONSTRATION/VALIDATION OF SOL-GEL SURFACE PREPARATION FOR METAL ADHESIVE BONDING

Team Participants

• *USAF AFRL/MLSA*	**Mr. Jim Mazza**
• *Naval Air Systems Command*, Pax River	**Mr. Matt Tillman**
• *US Army TACOM-ARDEC*	**Mr. Bill De Piero**
• *USAF WR-ALC/LBRE*	**Mr. Jay Fiebig**
• **USAF WR-ALC/EN**	**Mr. Bill Schweinberg**
• *NAVAIR-NADEP Jacksonville*	**Dr. Don Knapp**
• *NAVAIR-NADEP Cherry Point*	**Mr. Bill Alexander**
• *NAVAIR-NADEP North Island*	**Mr. Doug Perl**
• *US Coast Guard*	**LCDR Werner Winz**
• *The Boeing Company*	**Dr. Kay Blohowiak**
• *Advanced Chemistry & Technology*	**Mr. Stephane Pyrek**

AFRL/MLSA NAVAIR TACOM-ARDEC BOEING

Environmental Reduction Targets

- **Aluminum**
  - Pasa-Jell 105
    - **Hexavalent Chromium, Sulfuric Acid, Contaminated Waste Water**
  - FPL Etch
    - **Hexavalent Chromium, Sulfuric Acid, Contaminated Waste Water**
- **Titanium**
  - Chromic Acid Anodizing
    - **Hexavalent Chromium, Hydrofluoric Acid, Contaminated Waste Water**
  - Phosphate Fluoride Etch
    - **Hydrofluoric Acid, Phosphoric Acid, Contaminated Waste Water**
  - Pasa-Jell 107
    - **Hexavalent Chromium, Chromic Acid, Nitric Acid, Hydrofluorosilicic Acid, Contaminated Waste Water**
- **Steel**
  - Ferric Chloride/Hydrochloric Acid Etch
    - **Hydrochloric Acid, Sulfuric Acid, Contaminated Waste Water**

Designed Sol-Gel Interface

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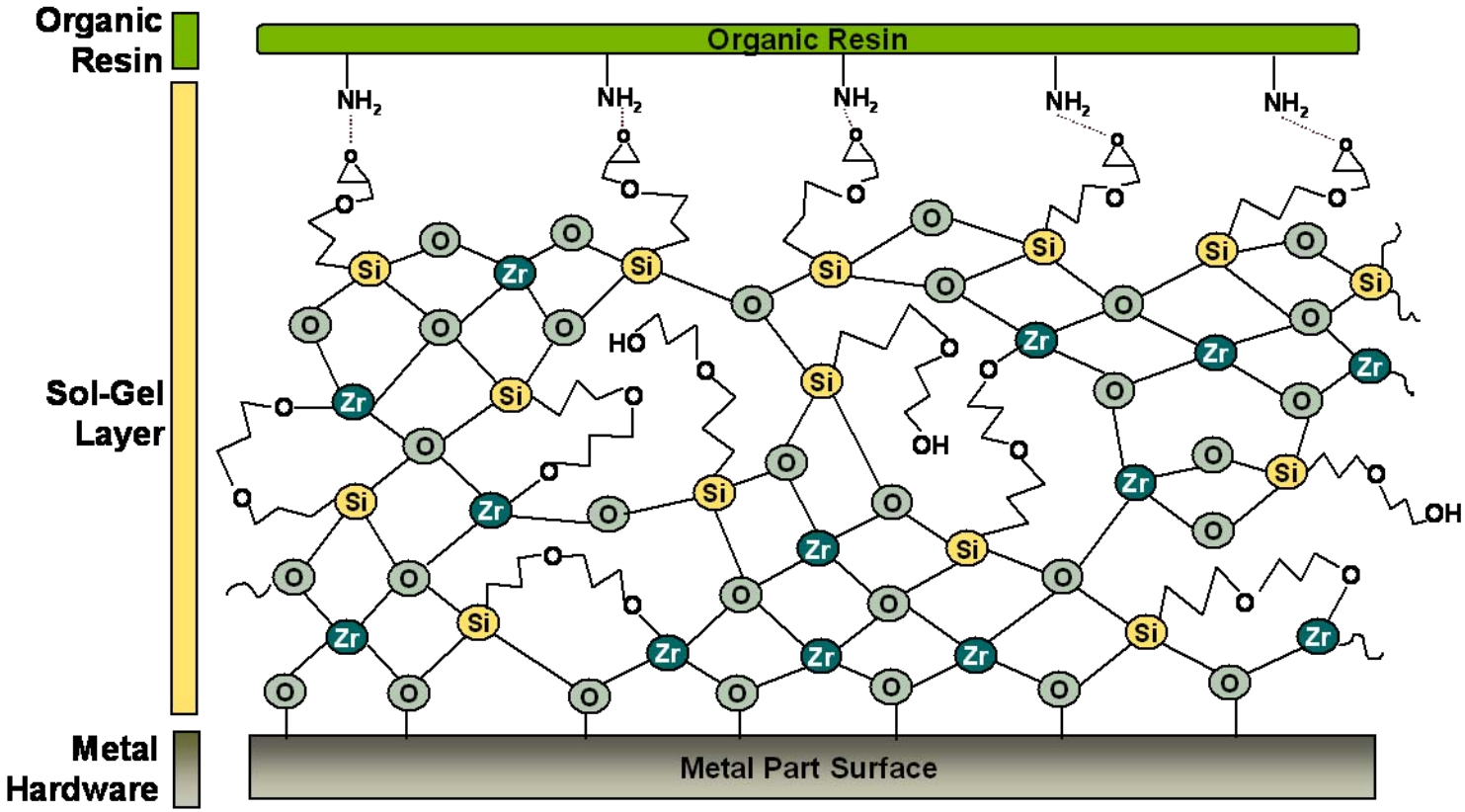

- Tailorable to different resin/paint chemistries
- Robust process conditions
- Greater range of properties using inorganic and hybrid polymers than current state-of-the art systems

Repair vs. OEM

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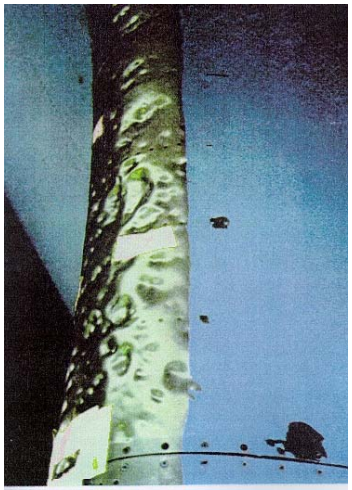
- Typically better controls at manufacturing level
  - Environmental controls
  - QC/inspection methods
- Fewer tools/materials available in field
- Training/certification
- New clean parts vs. dirty old parts
- Access to repair area
- Potential damage to areas adjacent to repair

Why we repair…



Sol-Gel Process Conditions

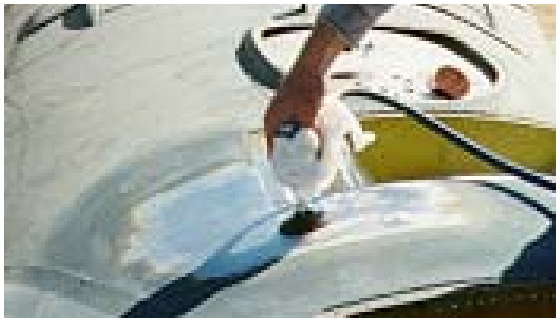
Mix AC-130 sol-gel kit

Induction time: 30 min

Sol-Gel Process Steps

Clean and deox Al alloy surface

Use specified sanding tools



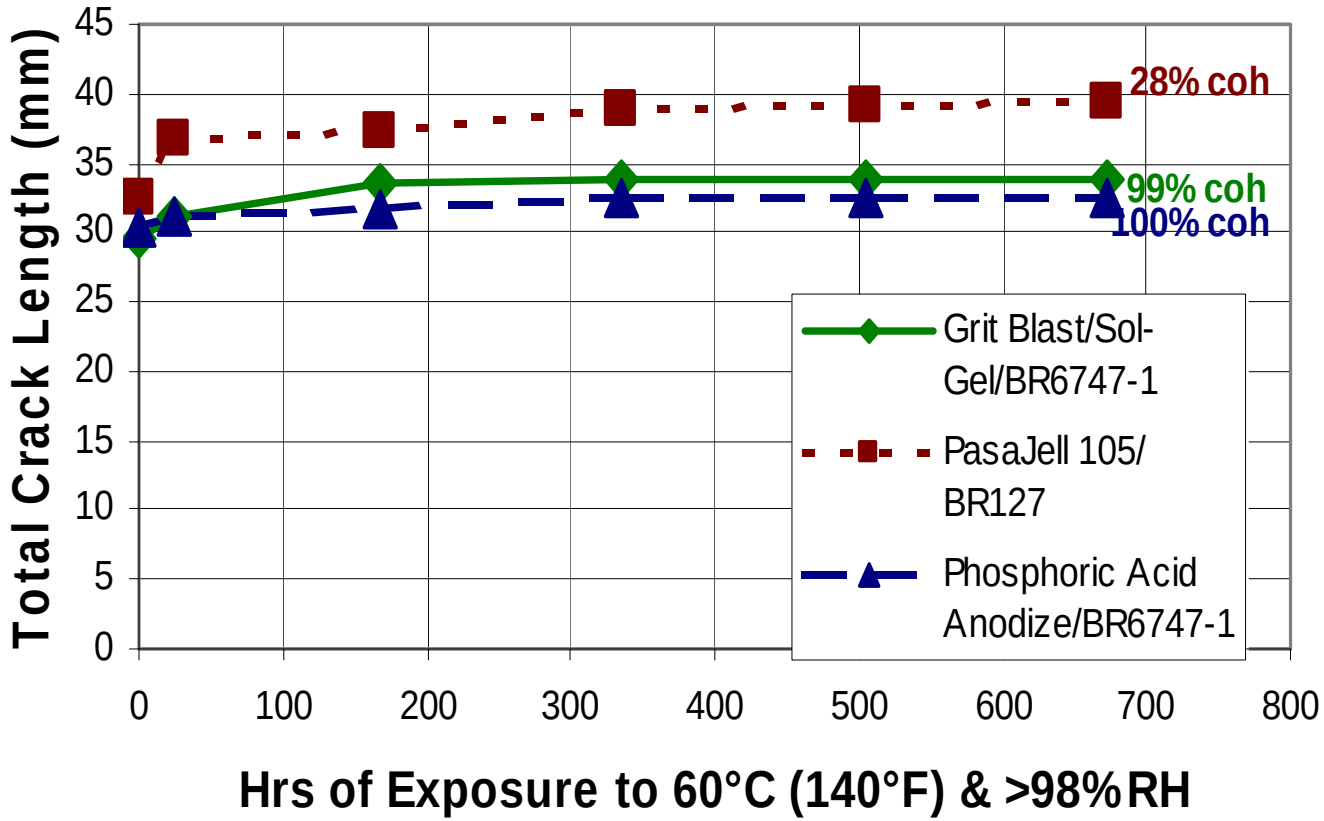
Brush or spray apply sol-gel

Dry 30 min

Spray apply BR6747-1

Cure with heat

Surface Treatment Comparison



Grit blast treatment prior to sol-gel gives a comparable result to PAA pretreatment, but is more difficult than manual abrasion in field repair applications.

WR-ALC TESTING

FATIGUE

STATIC STRESS DURABILTIY

THERMAL SHOCK

Examples of Repair Implementations

•**C-5 Applications**:
- •Flaps, Ailerons, Engine Pylon Panels, Floorboards, Torque Deck, Fuselage, Bulkheads, Ramps
- •Depot Level, Off-Aircraft Repair

•**V-22 Al Repairs**

•**F-18 Al and Ti Repairs**

•**F-16 Al Repairs**

•**C-130 Al Repairs**

•**CH-46 and CH-47** Ti and Al:
Rotor blade caps,
erosion strips, underfloor
corrosion repairs

•**B-1 Stainless Repair**

•**F-22 Ti Repairs**

OEM Sol-Gel Non-Cr Conversion Coatings

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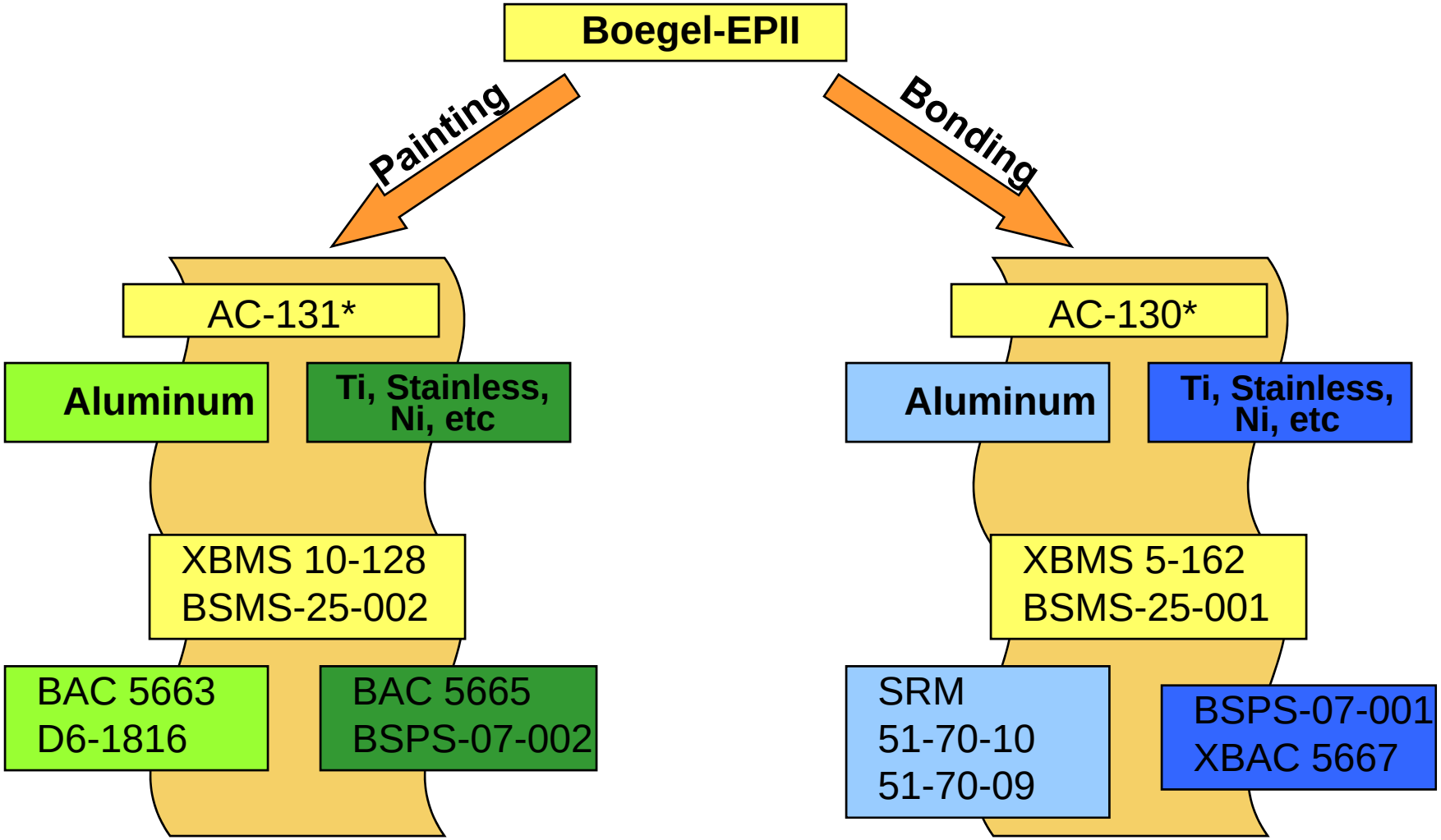

*AC-130 and AC-131 are products of AC Technology, Costa Mesa, CA, 2nd source supplier qualification currently in-work (Henkel, Socomor, PPG)

Qualification Test Matrix

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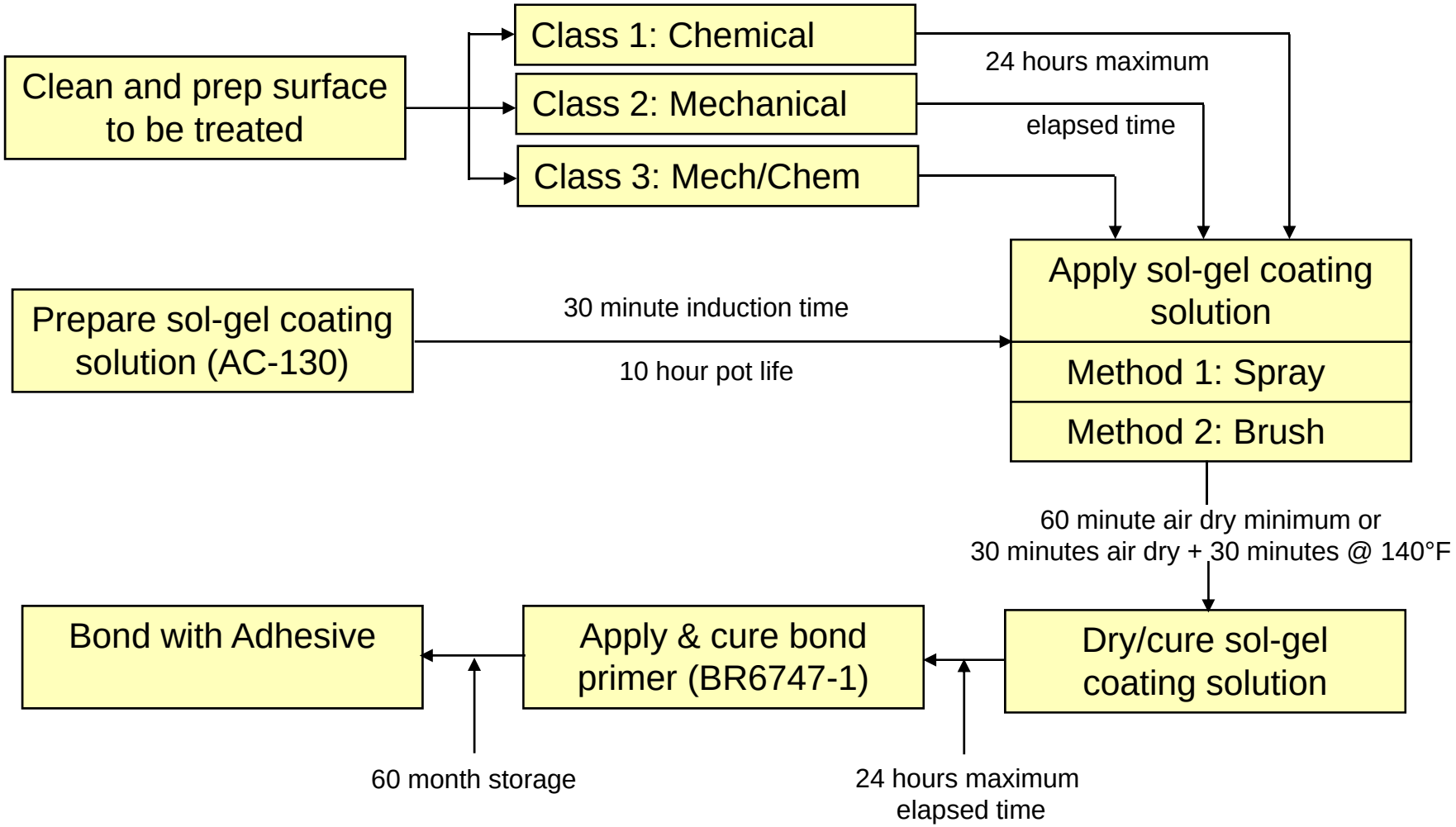
TEST	TEST METHOD	TEST PROCEDURE	No. of Specimens*	MINIMUM REQUIREMENT
Lap Shear at 75 ± 5°F	**BSS7202**	**BSS7202 Type V**	**10**	**4200 psi**
Lap Shear at -67 ± 2°F	**BSS7202**	**BSS7202 Type V**	**10**	**4200 psi**
Lap Shear at 180 ± 5°F	**BSS7202**	**BSS7202 Type V**	**10**	**3100 psi**
Lap Shear at 250 ± 5°F	**BSS7202**	**BSS7202 Type V**	**10**	**650 psi**
Lap Shear at 75 ± 5°F after 30 days at 120 ± 5°F and 100% Relative Humidity	**BSS7211 BSS7202**	**BSS7202 Type V**	**10**	**4200 psi**
Lap Shear at 75 ± 5°F after 30 days salt spray exposure at 95 ± 5°F	**BSS7210 BSS7202**	**BSS7202 Type V**	**10**	**3100 psi**
Lap Shear at 75 ± 5°F after 7 days immersion in Jet A fuel at 75 ± 5°F	**BSS7212 BSS7202**	**BSS7202 Type V**	**10**	**4200 psi**
Lap Shear at 75 ± 5°F after 7 days immersion in Reference Fuel B at 75 ± 5°F	**BSS7212 BSS7202**	**BSS7202 Type V**	**10**	**4200 psi**
Lap Shear at 75 ± 5°F after 7 days immersion in BMS3-11 at 150 ± 5°F	**BSS7212 BSS7202**	**BSS7202 Type V**	**10**	**4200 psi**
Lap Fatigue at 75 ± 5°F	**BSS7201**	**BSS7202 Type IIIA**	**3**	**10^7 cycles at 1500 psi**
Sustained Stress Loading at 140 ± 5°F and 100% Relative Humidity	**BSS7209**	**BSS7202 Type V**	**10**	**90 days at 900 psi**
Metal to Metal Climbing Drum Peel	**BSS7206**	**BSS7206 Type II**	**10**	**25 lbf/in width**
Wedge Crack after 7 days at 140 ± 5°F and 95% Relative Humidity	**BSS7202**	**ASTM D3762**	**10**	**<0.25 inch crack growth >90% cohesive failure**

*per batch for three batches for qualification

Sol-Gel Process Steps



BCA Adhesive Bonding Repair Process

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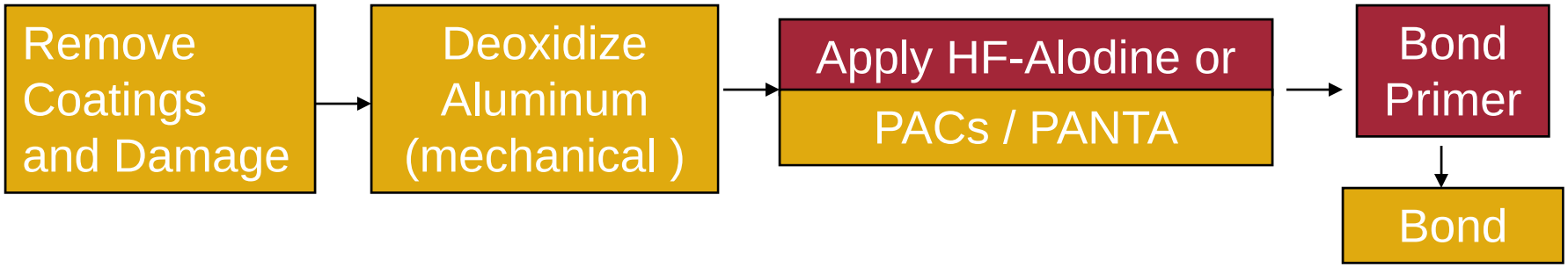

- Added as an option to SRM 51-70-09 and 51-70-10 Implemented 2005-2006
  - Al 250F-cure repairs w/BMS 5-101
  - Al 350F-cure repairs w/BMS 5-137
  - Titanium repairs
- Only BMS 5-89 Ty II (Cytec BR 6747-1) allowed with Boegel-EPII
  - Compatibility of water-based product with sol-gel
- Goal: Replace HF/Alodine in fleet repairs
  - Health/Safety/Hazmat
  - Improved Durability
- Reduce process repair time/cost over anodize repair methods
- Uses specific abrasive materials and tools
- Robust process methods

Performance Comparisons

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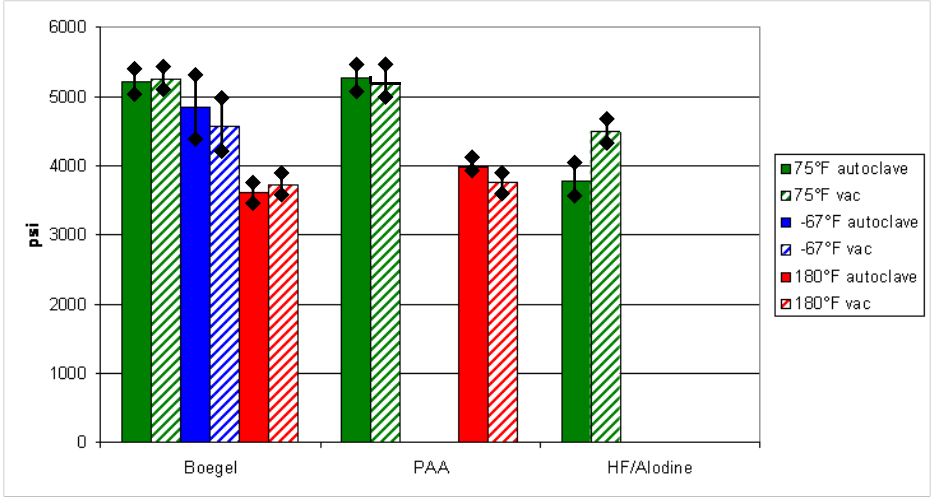
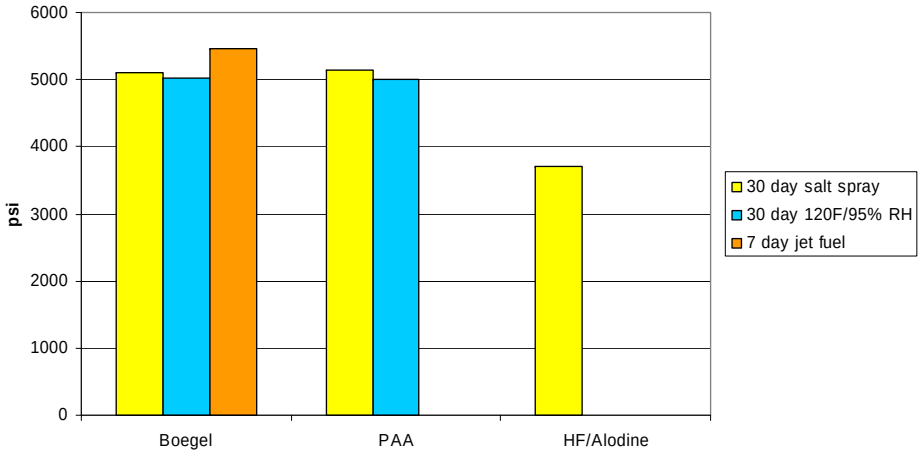
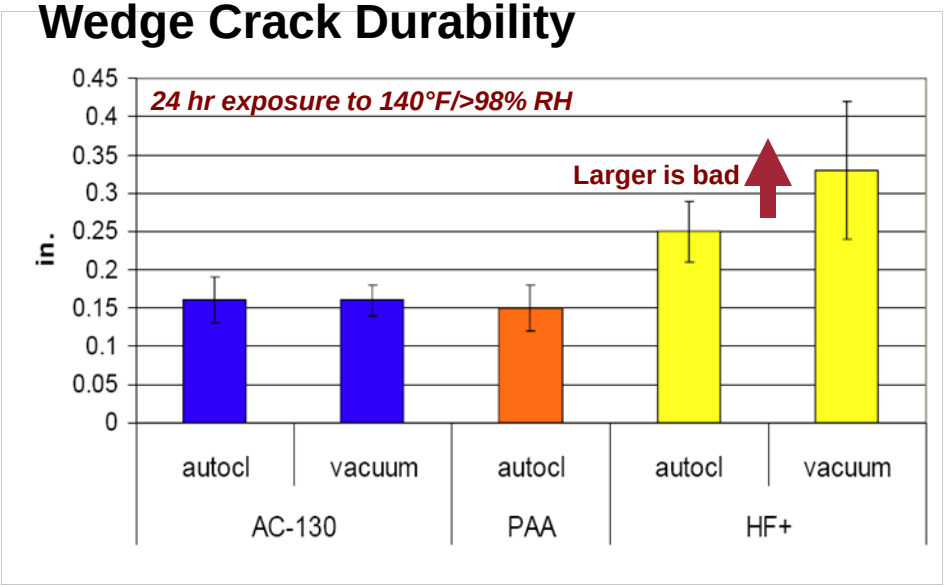
Lap Shear Testing



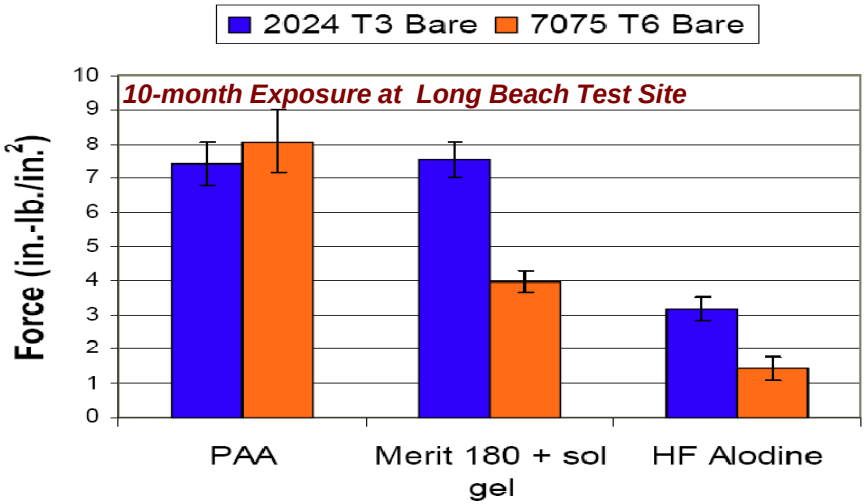
Lap Shear with Environmental Exposure



Wedge Crack Durability



DCB Extended Durability Tests



BCA Repair Implementation

- **Implemented in the Boeing Commercial Structural Repair Manuals in 2005**
  - **Metalbond Working Group**
    - **Airlines, Boeing R&D, Service Engineering, DERs**
- **Aluminum 250F repairs first**
  - **Added 350F Al repairs**
  - **Added Ti repairs**
- **Feedback from airline users good**
  - **Cost savings**
  - **Process robustness**
  - **Wanted some improvements**

Boegel-EPII for Al Bonding Updates

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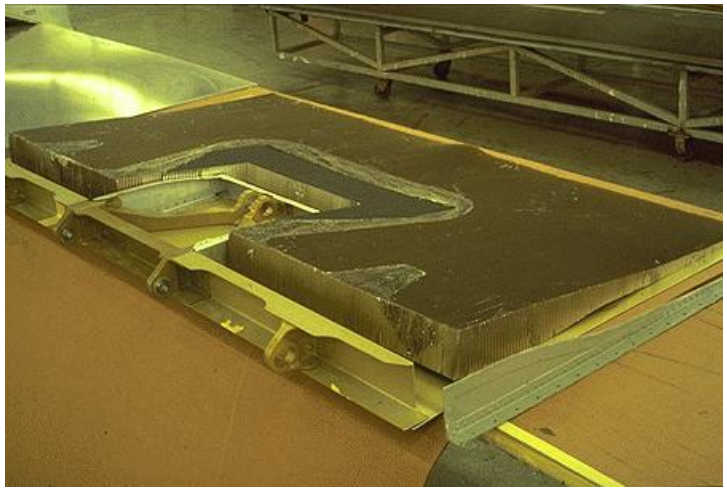
- Added new sandpaper alternatives for use in Al bonded repairs
  - 3M 361F, 300D, 777F, 900DZ
  - Merit ALO Resin Bond
- Incorporated 2-part Boegel kits (AC-130-2) into BCA SRMs
  - More stable shelf-life
  - Easier shipping to overseas locations
  - More robust, easier to use
  - Equivalent performance and durability
- Working on draft BMS/BAC for internal OEM Al bonding applications
- Testing new nonchromated adhesive bond primers
  - Cytec BR6747-1NC
  - Cytec BR6700-1 (sol-gel compatible)
  - Initial data promising



Adhesive Bond Repair

Composite Patch Repair

Future Work – Deoxidation Methods

- **Alternatives to Abrasive Deoxidation Methods**
  - **Improve robustness of process**
  - **Reproducibility over larger areas**
  - **Evaluate energetic techniques**
    - **Plasma**
    - **Laser**

Future Work – Bond Primer

- **Non-Chromated Adhesive Bond Primers**
  - **Preliminary data on 3M and Cytec candidates**
  - **Compatibility with Multiple Surface Prep Methods**
    - **PAA**
    - **Sol-Gel**
  - **Corrosion Protection within Bondline and Outside of Bondline**
  - **Non-Aluminum Applications**
    - **Want one primer for all**
  - **Industry Team**
    - **March Telecon; Spring 2008 SAMPE meeting**
    - **Contact kay.y.blohowiak@boeing.com to get on the distribution list for participation**

Future Work – Other Bonded System Improvements

- **Composites bonding**
  - **Reduce haz/mats used**
- **Improved Adhesive Systems**
  - **Improved durability – longer life**